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STRUCTURE AND KINEMATICS OF THE MOLECULAR SPIRAL ARMS IN M51

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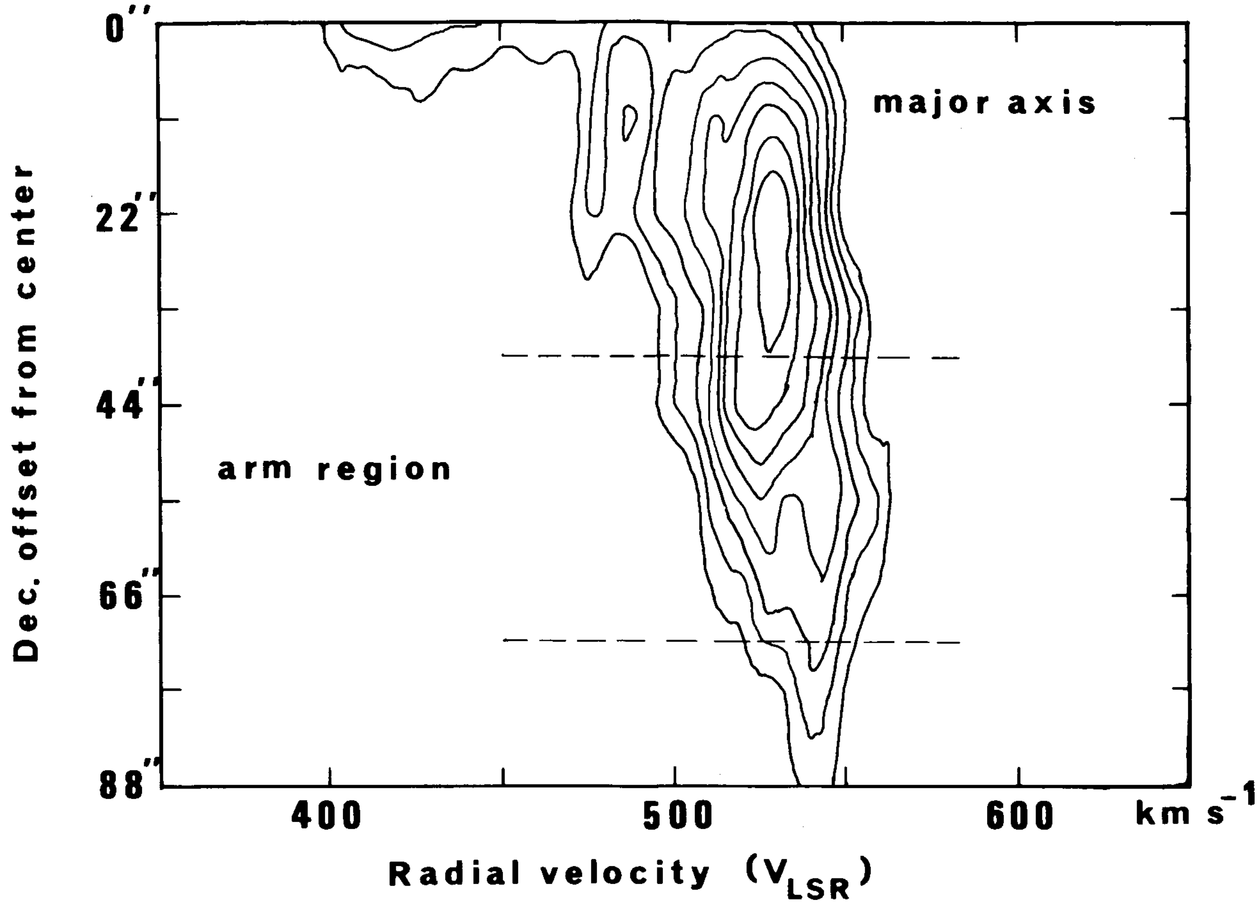
Mapping of the CO(1-0) emission from the spiral galaxy M51 has been made with the Onsala 20 m antenna (HPBW=33"). The observations show that the emission is considerably enhanced - above the background disk distribution - in spiral arms which appear to originate as intense ridges of emission about 1 kpc from the nucleus (assuming a distance of 9.6 kpc). Inside this region there is virtually no emission (Rydbeck et al., 1985b; cf. also the FIR results by Lester et al., 1986). Arm-interarm ratios (defined as in Rydbeck et al., 1985b) along the observed arm (arm r,p in Tully, 1974, Fig. 10), vary between 1.1 and 2.5, with an average of about 1.4. The beam deconvolved arm-interarm contrasts are likely to be higher, however. The excess emission along the arm is broken up into large scale patches of up to a few kpc in size. This suggests that the "on-arm" molecular clouds are assembled into giant complexes with hydrogen masses estimated to be up to 10^8 $M_\odot$, using the Young and Scoville (1982) "empirical" conversion factor of integrated CO to H_2 mass. Cloud parameters could be very different in this case, however, making the determination rather uncertain.

One of the main objectives for the 1986 observations was to study the variations of the tangential velocity component of molecular gas across a spiral arm. The radial velocity component was studied in Rydbeck et al. (1985a,b) where it was found to have a velocity shift similar to that predicted by density wave theory. Note that tangential and radial velocities are observed along the major and minor axis, respectively.

The present (1986) observations of the inner southern spiral arm of M51 (containing the southern part of the major axis, its position angle being -10°) show that also the tangential velocity component behaves in a way which conforms with density wave theory. As one crosses the spiral arm radially outwards (see Figure) the tangential velocity first displays a gradual decrease followed by a sudden increase the velocity slowly decreases again. As was found for the radial velocity component the sudden change in tangential velocity is rather large (50-70 km s^{-1}, depending on the inclination) compared to what is usually expected from density wave models ($\approx$30 km s^{-1}, Roberts and Hausman, 1984, cf. also numerical simulations of tidal interactions by Sundelius et al., 1986). It thus appears that the density wave in M51 is comparatively strong.

Looking more closely at the rapid velocity change in the position-velocity maps, we find that going radially outwards this velocity shift, in most cases appears as a new component spatially overlapping the old one, while in general there appear to be less clouds with "intermediate" velocities. In some cases, however, e.g. in crossing the largest cloud complex (around position 8,8 in Rydbeck et al., 1985a, or near position p in Tully, 1974, Fig. 10), the clouds appear to evenly fill the whole velocity gap (c.f. Figure 12a in Rydbeck et al., 1985b), but still overlap spatially.



From the structure of our position-velocity maps it seems that these results cannot be explained by beam or sidelobe effects. Higher resolution maps of some of these arm-regions would be highly desirable. Assuming that our interpretation above is correct it seems that fairly violent cloud-cloud collisions may occur in the arm regions. The occurance of high velocity cloud-cloud collisions may be important to the formation of massive stars in the spiral arms.

We have compared the molecular arms with the Hα ionized gas arms of Tully (1974) and find that the ionized gas appears to have its maximum intensity slightly outside the molecular arm. This apparent phase shift may be due to extinction by dust. However, the molecular gas seems to have a systematically lower velocity than the ionized gas (Rydbeck et al., 1985b, Fig. 9), so a correlation between the arm maxima for the molecular and the ionized gas is not obvious, though the most intense non-central Hα emission does occur on the north-eastern molecular cloud complex.

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